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*Draft*

# **In-Situ Chemical Oxidation Treatability Study Work Plan**

**Operable Unit 1  
Quanta Resources Site  
Edgewater, NJ**

Prepared for  
**USEPA Region 2**

On behalf of  
**Honeywell**  
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February 2007

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# Acronyms and Abbreviations

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CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DNAPL	dense non-aqueous phase liquid
FS	feasibility study
FSP	Field Sampling Plan
GCI	Geo-Cleanse® International, Inc.
ISCO	in situ chemical oxidation
NAPL	non-aqueous phase liquid
NJDEP	New Jersey Department of Environmental Protection
NPL	National Priorities List
OU	operable unit
PAHs	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyl
PID	photoionization detector
QAPP	Quality Assurance Project Plan
RI/FS	remedial investigation/feasibility study
SVOC	semivolatile organic compound
TOC	total organic carbon
TPH	total petroleum hydrocarbons
USEPA	U.S. Environmental Protection Agency
VOC	volatile organic compound

## SECTION 1

# Introduction

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This Treatability Study Work Plan describes supplemental tasks that are to be conducted in conjunction with ongoing remedial investigation/feasibility study (RI/FS) activities described by Parsons (2005a) and CH2M HILL (2006a) for the upland portion (Operable Unit 1 [OU1]) of the Quanta Resources Site, located in Edgewater, New Jersey.<sup>1</sup> Bench-scale treatability testing will be conducted to evaluate in-situ chemical oxidation (ISCO) for treating soil with pure phase coal tar, residual coal tar adsorbed to soil, and dissolved coal tar constituents in groundwater. The results of the evaluation in the treatability study will be used during the FS to develop remedial alternatives for the different impacted media and areas at OU1.

Most technologies and process options included in the Technology/Process Options Table, transmitted on November 21, 2006 with the response to comments on the Identification of Candidate Technologies Memorandum (CH2M HILL, 2006b), were not recommended for treatability testing for one of the following reasons:

- The effectiveness of the technology has been demonstrated.
- Data that would be obtained from treatability testing is not necessary for completion of the FS, though it may be required in the future to support remedy design.

Although the technology has recently been demonstrated at other coal tar sites, ISCO may have varying effectiveness on different types of Site media (i.e., silty sand vs. peat). The target constituents for this treatability test are limited to coal tar-related constituents in order to focus the test on the most widespread contaminant type at the site. Future treatability tests for technologies targeting other site constituents such as metals may be warranted as part of pre-design work, but are not required prior to the feasibility study (FS).

ISCO has been demonstrated at several sites to effectively treat non-aqueous phase liquid (NAPL). While this treatment has been applied successfully at sites for chlorinated solvents, the application of the technology to remediate coal tar NAPL and polycyclic aromatic hydrocarbons (PAHs) is less proven and requires more innovative approaches. The study will include tests on two soil types (silty sand and peat), and the data collected from this study will be used to evaluate ISCO treatment technology in the FS being prepared for OU1. While the effectiveness of the technology is one criteria being assessed during the treatability testing, the other eight FS evaluation criteria will also be considered, including cost, implementability and community/regulatory acceptance. As a result, ISCO may be deemed a viable remedy for some areas within OU1, while deemed infeasible for other portions of OU1.

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<sup>1</sup> As defined in the Administrative Order on Consent II-CERCLA-2003-2012, the Quanta Resources Superfund Site includes the Quanta Resources property, located on River Road in Edgewater, New Jersey, and any areas where contamination from the property has come to be located. The current extent of the Quanta Resources property (referred to herein as the "Quanta Resources property") refers to Block 95, Lot 1, as defined on the Borough of Edgewater, New Jersey tax map.

## 1.1 Site Location and Physical Setting

OU1 of the Site consists of approximately 15 acres of a former industrial area of Edgewater, NJ, adjacent to the Hudson River. OU1 includes the Quanta Resources property at 163 River Road and portions of adjacent properties. The former Quanta Resources property was bisected in 1995 and 1996 by the realignment of River Road, which now runs north-south through the western portion of OU1. Surface water and sediment in the Hudson River adjacent to the Site make up OU2, which is not included in this treatability test.

## 1.2 Site Background

Portions of the Site were used to process coal tar and manufacture paving and roofing materials from approximately 1876 to 1974. The Site was then used for the storage and recycling of oil from 1977 to 1980. The New Jersey Department of Environmental Protection (NJDEP) ceased facility operations at the Site in 1981 after it was discovered that large quantities of oil – including some with concentrations of polychlorinated biphenyls (PCBs) – were present in storage tanks at the facility; after this, the property was no longer in use.

NJDEP requested that the U.S. Environmental Protection Agency (USEPA) address Site contamination pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly known as "Superfund." Several removal actions were conducted by Honeywell at the Site from 1984 to 1988 under USEPA oversight.

On September 9, 2002, USEPA placed the Site on the National Priorities List (NPL). In 2004, Honeywell and USEPA agreed that an RI/FS would be conducted to fill data gaps in previous investigations and provide a basis for a complete evaluation of alternatives in the FS. The majority of the field investigation at OU1 has been completed and the RI is currently being prepared.

## 1.3 Purpose

Bench-scale treatability testing will be conducted to evaluate the effectiveness of Fenton's reagent and sodium persulfate oxidation on coal tar constituents present in two soil types (silty sand and peat) and groundwater at the Site and to estimate total oxidant demand. The results of the study will help evaluate ISCO as a treatment technology option in the feasibility study (FS) for OU1 as a means to reduce concentrations in source zone or residually-impacted soils at the Site and to potentially reduce dissolved concentrations of coal tar-related PAHs in groundwater. In addition, the study will provide data that will allow a determination of whether an application of ISCO to address coal tar constituents at the Site may have an impact on other constituents present at the Site (i.e., arsenic).

## SECTION 2

# Objectives and Approach

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## 2.1 Objectives

The objectives of the treatability study on the soil and groundwater from the Site are to:

- Determine whether ISCO technology is likely to be applicable for source zones, residual areas of coal tar contamination in soil and groundwater, or both
- Determine the relative ability of Fenton's reagent and sodium persulfate to reduce coal tar constituent concentrations in Site media
- Quantify the reduction of coal tar constituent concentrations in media from the Site after treatment with each ISCO reagent
- Estimate total oxidant demand of contaminated media
- Determine the relative fractions of contaminants oxidized, volatilized, and leached during the treatment process
- Evaluate the effect of ISCO reagent application on other constituents present at the Site, including arsenic, to ensure a secondary hazard is not created

## 2.2 Approach

Soil samples will be collected with an excavator in accordance with the original OU1 Field Sampling Plan (FSP) (Parsons, 2005b) and the OU1 FSP Addendum for Treatability Testing (Appendix A). Groundwater will be collected from the nearest well to each soil sampling location. The three general soil types encountered at the site will be included in the testing to gain an understanding of how each ISCO reagent will work on the various soils present at the site. The three soil types are:

- Silty sand with visible coal tar (SS-1)
- Silty sand with residual coal tar (SS-2)
- Peat with residual coal tar (P-1)

Soil sampling locations (Figure 1) were determined based on data collected during the OU1 Supplemental Investigation TarGOST™ study conducted in October 2006 in accordance with the Draft RI/FS Work Plan Addendum (CH2M HILL, 2006c). Bench-scale treatability testing will be performed by Geo-Cleanse® International, Inc. (GCI) at their facility in Kenilworth, NJ, and the results will be evaluated by CH2M HILL in concert with GCI. Information pertaining to GCI's capabilities and experience are summarized at [www.geocleanse.com](http://www.geocleanse.com). Qualifications of key personnel are provided in Appendix B of this work plan.

The following amounts of each soil type and groundwater will be required to perform the testing:

- 77 lbs (35 kg) of SS-1 and 5 gallons (18 L) of groundwater
- 33 lbs (15 kg) of SS-2 and 5 gallons (18 L) of groundwater
- 33 lbs (15 kg) of P-1 and 5 gallons (18 L) of groundwater

Each of the three soil samples from the Site will be homogenized and samples will be collected from the homogenized material for laboratory analysis of volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and total iron. Each of the three groundwater samples will be analyzed for VOCs, SVOCs, arsenic (III), arsenic (V), manganese, phosphates, sulfates, ferrous iron, total iron, total chromium, chromium (VI), total organic carbon (TOC), and total petroleum hydrocarbons (TPH). The total contaminant mass will be estimated for each location on the basis of the baseline sampling results. These results will be used as a baseline of comparison with the results of each bench test.

A soil buffering test and a reactivity test will be conducted on each of the three soil samples. Two types of bench-scale tests will be conducted: a 50 percent soil-groundwater slurry test and an autoclave test. Two different ISCO reagents will be tested: Fenton's reagent and sodium persulfate. Lastly, a residual NAPL saturation test will be performed to evaluate and document NAPL destruction during oxidation and changes in leachate throughout the test. A detailed description of the scope of work for each of the five tests is provided in Appendix B, which also provides qualifications for key GCI personnel. A summary of each of the tests is provided below and in Table 1.

### **2.2.1 Soil Buffering Test**

A soil buffering test will be performed on each of the three soil/groundwater samples to evaluate the buffering capacity of the media. A mixture of soil and groundwater will be created and an acidic solution will be added incrementally (as drops) at 5-minute intervals until the mixture achieves a steady pH of between 4.0 and 5.0. Time, pH, and amount of acid added to the mixture will be recorded and used to calculate the buffering capacity of the sample.

### **2.2.2 Reactivity Test**

The reactivity of the soil to hydrogen peroxide will be tested by adding a set amount of hydrogen peroxide to each soil type and observing and documenting the reaction.

### **2.2.3 Slurry Test**

Site groundwater and soil from each of the three locations will be combined to form a 50 percent soil slurry (equal parts soil and groundwater), which will then be tested with Fenton's reagent and with sodium persulfate at varying doses. The slurries will be allowed to equilibrate for 8 to 16 hours prior to oxidant addition.

There will be three different tests for each soil type and oxidant type (each with a different volume of oxidant and mass ratios):

- 10:1 sample (mass ratio of 10 grams oxidant per 1 gram contaminant)
- 20:1 sample (mass ratio of 20 grams oxidant per 1 gram contaminant)

- 40:1 sample (mass ratio of 40 grams oxidant per 1 gram contaminant)

Testing of the three different soil types with each reagent type and varying reagent doses will occur at the same time. Once the oxidant is added the samples will be gently shaken and allowed to react until residual peroxide or persulfate is consumed in all of the test reactors. Samples will be periodically agitated throughout the test. Solution pH and iron concentration will be adjusted by addition of catalyst. The treated slurries will be drained of water and then testing will be conducted on the soil and water separately. Treated samples will be analyzed as follows:

- Groundwater from the 20:1 test reactors will be analyzed for VOCs, SVOCs, arsenic (III), arsenic (V), manganese, nitrates, phosphates, sulfates, ferrous iron, total iron, total chromium, chromium (VI), TOC, and TPH.
- Groundwater from the 10:1 and 40:1 test reactors will be analyzed for VOCs, SVOCs, pH, and iron concentration.
- Soil samples will be analyzed for VOCs, SVOCs, and total iron.

## 2.2.4 Autoclave Test

An autoclave test for each oxidant will be performed on an SS-1 soil sample/groundwater slurry at the 20:1 ratio to determine the effectiveness of each oxidant on the destruction of PAH constituents in the sample. This type of bench study is a closed system that permits oxidation in each phase to be accurately measured. A representative soil sample is put into a sealed vessel that has ports to capture leachate and offgas. Oxidant and catalyst are injected into the vessel while photoionization detector (PID) headspace, carbon dioxide and oxygen offgas are monitored to determine the progress of the reaction. When the reaction reaches completion, the soil, leachate, and offgas are recovered and analyzed to determine target compounds. These data will allow computation of a complete mass balance for the reaction.

## 2.2.5 Residual Saturation Test

A residual NAPL saturation test will be performed on an SS-1 sample for each oxidant at the 20:1 ratio. To confirm the destruction of NAPL during the test, headspace will be monitored with a photoionization detector (PID), and carbon dioxide and oxygen off-gas will be monitored. The treated soils will be analyzed for VOCs and SVOCs to determine the destruction of NAPL. The changes in the leachate throughout the test and the condition of the soil post-treatment will be recorded to document NAPL desorption and oxidation. If residual NAPL remains following the column test, the material will be sampled and analyzed for VOCs, SVOCs, and TPH.



SECTION 3

## **Quality Assurance/Quality Control**

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Quality Assurance and Quality Control (QA/QC) samples and field procedures will be collected and performed in accordance with the FSP Addendum (Appendix A) and current Site-specific Quality Assurance Project Plan (QAPP) (CH2M HILL, 2006a).

#### SECTION 4

## **Data Management and Reporting**

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The results of the treatability study will be summarized in a technical memorandum and included in the FS report. The analytical data and technical memorandum will be submitted to USEPA prior to or with the draft FS report for OU1.

## SECTION 5

# Schedule

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Procurement, mobilization, and implementation of the work plan would begin immediately following USEPA authorization to proceed. The approximate durations of tasks associated with this work plan are presented below. Upon verbal authorization to proceed with the activities described in this work plan, mobilization, sample collection, and treatability testing would begin.

Task	Estimated Duration
USEPA review of Treatability Study Work Plan	
Revision and submission of Final Work Plan (if necessary)	1 week
USEPA review and authorization to proceed with treatability study	2 weeks
Procurement, mobilization, and sample collection	2 weeks
Treatability testing and laboratory analysis of samples	6 weeks
Data evaluation and preparation of technical memorandum	5 weeks

## SECTION 6

# References

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CH2M HILL. 2006a. Quality Assurance Project Plan (Revised), Operable Unit 1, Quanta Resources Site, Edgewater, New Jersey. November.

CH2M HILL. 2006b. Draft Identification of Candidate Technologies Memorandum, Operable Unit 1, Quanta Resources Site, Edgewater, New Jersey. February.

CH2M HILL. 2006c. Draft Remedial Investigation/Feasibility Study Work Plan Addendum, Operable Unit 1, Quanta Resources Site, Edgewater, New Jersey. July.

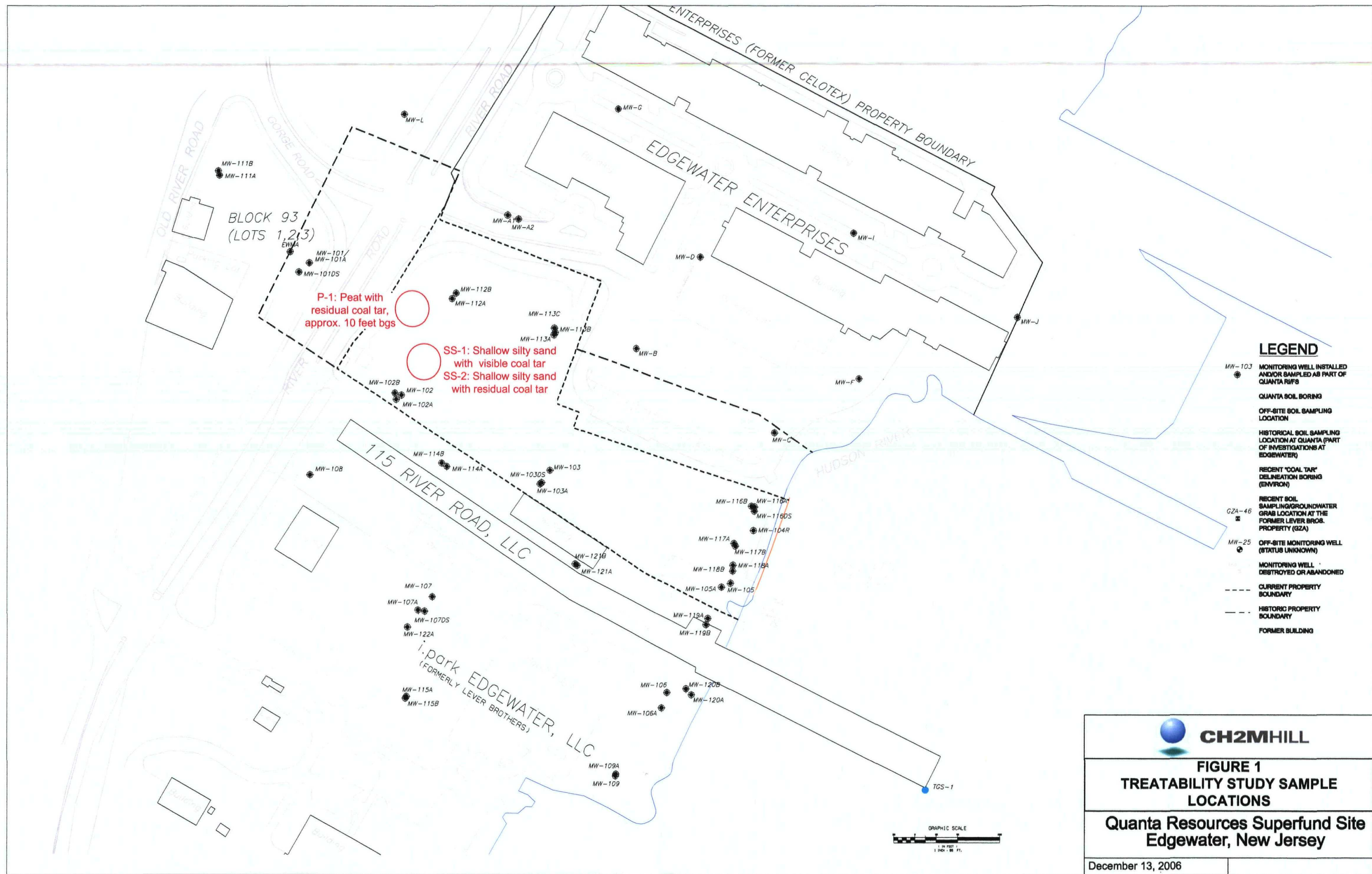
Parsons. 2005a. Remedial Investigation/Feasibility Study Work Plan, Operable Unit 1, Quanta Resources Site, Edgewater, New Jersey. May.

Parsons. 2005b. Field Sampling Plan, Operable Unit 1, Quanta Resources Site, Edgewater, New Jersey. May.

TABLE 1  
Treatability Testing Summary Table  
Quanta Resources Site, Operable Unit 1

Test	Objectives	Test Method	Soils Tested	Reagents Tested	Reagent Doses	Groundwater Analyses	Soil Analyses	Other Analyses
Slurry Test	Compare sodium persulfate to Fenton's reagent  Determine the necessary dose of reagent	Groundwater and soil will be combined to form a 50 percent soil-slurry (equal parts soil and groundwater), which will then be tested with the ISCO reagents at varying doses.	SS-1	Sodium persulfate	10:1 mass ratio (reagent to contaminant)	10:1 and 40:1 doses - VOCs, SVOCs, pH and total iron  20:1 dose - VOCs, SVOCs, arsenic (III), arsenic (V), manganese, nitrates, phosphates, sulfates, ferrous iron, total iron, total chromium, chromium (VI), TOC and TPH	10:1, 20:1 and 40:1 doses - VOC, SVOC and total iron	None
			SS-2	Fenton's reagent	20:1 mass ratio (reagent to contaminant)			
			P-1		40:1 mass ratio (reagent to contaminant)			
Soil Buffering Test	Evaluate the buffering capacity of each soil sample	A mixture of soil and groundwater will be created and an acidic solution will be added incrementally as drops at five minute time intervals, until the mixture achieves a steady pH of between 4.0 and 5.0.	SS-1	None	None	None	None	Time, pH, and amount of acid added to the mixture are recorded to determine the buffering capacity.
			SS-2					
			P-1					
Reactivity Test	Evaluate reactivity of the soil to hydrogen peroxide	A set amount of hydrogen peroxide will be added to each soil type and the reaction will be observed	SS-1	None	None	None	None	None
			SS-2					
			P-1					
Autoclave Test	Quantify the volatilized and leached contaminant mass	Volumes of solution will be injected into the autoclave and leachate collected will be monitored. Gas generated in the autoclave will be collected and the volatilized contaminant mass will be quantified.	SS-1	Sodium persulfate Fenton's reagent	20:1 mass ratio (reagent to contaminant)	None	VOCs	Gas traps will also be analyzed for VOCs to complete the mass balance
Residual Saturation Test	Visually confirm the destruction of NAPL during the test	Sample will be placed in a PVC column that is fitted with an inlet/outlet port. Oxidant will be added and the changes in the leachate throughout the test and the condition of the soil post-treatment will be recorded to document NAPL desorption and oxidation.	SS-1	Sodium persulfate Fenton's reagent	20:1 mass ratio (reagent to contaminant)	None	VOCs, SVOCs	If residual NAPL remains following the column test, it will be analyzed for VOCs, SVOCs, and TPH





**CH2MHILL**

**FIGURE 1**  
**TREATABILITY STUDY SAMPLE**  
**LOCATIONS**

**Quanta Resources Superfund Site**  
**Edgewater, New Jersey**

December 13, 2006

# **Field Sampling Plan Addendum for In-Situ Chemical Oxidation Treatability Study**

**Operable Unit 1**

**Quanta Resources Site  
Edgewater, NJ**

Prepared for  
**USEPA Region 2**

On behalf of  
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January 2007

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## A.1 Introduction

This addendum to the Field Sampling Plan (FSP) (Parsons, 2005) describes in detail select sampling and data-gathering methods to be used during treatability study field activities at the Quanta Resources Site (the Site) Operational Unit 1 (OU1). This FSP addendum includes only the sampling and data-gathering methods unique to the treatability study that were not part of the original FSP (Parsons, 2005). This addendum, together with the original FSP, serves as a complete FSP for all tasks associated with the treatability study and outlined in the Treatability Study Work Plan (CH2M HILL, 2007). Unless otherwise noted herein, the work described in this addendum will be conducted as part of the RI/FS investigation and will be performed in accordance with the applicable methods and procedures outlined in detail in the original FSP (Parsons, May 2005a).

This FSP should be used in conjunction with the revised Quality Assurance Project Plan (QAPP) (CH2M HILL, 2006) to guide all field and laboratory sampling and measurement conducted as part of the treatability study. Together, the original FSP, this addendum to the FSP, and the revised QAPP comprise the Sampling and Analysis Plan under the RI/FS process.

## A.2 Sampling Objectives

The objectives of the treatability study on the soil and groundwater from the Site are to:

- Determine whether ISCO technology is likely to be applicable for source zones, residual areas of coal tar contamination in soil and groundwater, or both
- Determine the relative ability of Fenton's reagent and sodium persulfate to reduce coal tar constituent concentrations in Site media
- Quantify the reduction of coal tar constituent concentrations in media from the Site after treatment with each ISCO reagent
- Estimate total oxidant demand of contaminated media
- Determine the relative fractions of contaminants oxidized, volatilized, and leached during the treatment process
- Evaluate the effect of ISCO reagent application on other constituents present at the Site, including arsenic, to ensure a secondary hazard is not created

The bench testing will be performed by Geo-Cleanse® International, Inc. The primary objective of the field work that CH2M HILL will perform as part of the Treatability Study will be to collect the necessary amounts of soil and groundwater to complete the scope of work of the Treatability Study Work Plan.

## A.3 Sample Locations

Field sampling activities to be conducted in support of the treatability study are described in this section. Quality assurance/quality control sampling will not be conducted due to the

nature of this sampling event. Field work will be performed using the general guidelines and investigative methods detailed in Sections 2, 3, 4, 5, 6, and 7 of the original FSP (Parsons, 2005), as well as in Section A.4 of this addendum to the FSP. The locations of sample investigation points are shown in Figure 1.

### **A.3.1 Soil Samples**

Soil samples will be collected at three locations on the Quanta Resources property in order to provide samples of the three different soil types identified in the treatability study:

- Silty sand with visible coal tar (SS-1)
- Silty sand with residual coal tar (SS-2)
- Peat with residual coal tar (P-1)

Soil samples will be collected using an excavator. At a minimum the following amounts of each soil will be collected:

- 77 lbs (35 kg) of SS-1
- 33 lbs (15 kg) of SS-2
- 33 lbs (15 kg) of P-1

All soil sampling locations are illustrated in Figure 1 of the ISCO Treatability Study Work Plan (CH2M HILL, 2007).

### **A.3.2 Groundwater Samples**

Groundwater samples will be collected from three monitoring wells at the Quanta Resources Property. For each soil sample collected, groundwater will be collected from the nearest monitoring well in order to create the soil slurries that will be used for the bench tests described in the treatability study work plan. Groundwater from the following wells will be collected for each of the following soil sample locations:

- MW-102A for (SS-1)
- MW-102 for (SS-2)
- MW-112A or MW-112B (P-1)

Groundwater samples will be collected with a peristaltic pump. A minimum of five gallons of groundwater from each well will be collected.

## **A.4 Sampling Equipment and Procedures**

Wherever applicable sampling activities will be performed using the applicable equipment and procedures outlined in Sections 2, 3, 4, 5, 6, and 7 of the original FSP (Parsons, 2005).

### **A.4.1 Soil Samples**

Soil samples will be collected using an excavator by a New Jersey licensed operator. Because the sampling locations are on the Quanta Resources Property which has already been cleared for subsurface work for past RI/FS activities it will not be necessary to have a utility clearance performed prior to sample collection. Sample material will be collected from the excavator bucket by a CH2M HILL staff member. The material will be placed into

containers and transported to GCI by a GCI staff member under standard chain-of-custody protocol.

#### **A.4.2 Groundwater Samples**

Groundwater samples will be collected with a peristaltic pump by a CH2M HILL staff member. The material will be placed into containers and transported to GCI by a GCI staff member under standard chain-of-custody protocol.

### **A.5 References**

CH2M HILL. 2007. In-Situ Chemical Oxidation Treatability Study Work Plan, Operable Unit 1, Quanta Resources Site, Edgewater, New Jersey. January.

CH2M HILL. 2006. Quality Assurance Project Plan (Revised), Operable Unit 1, Quanta Resources Site, Edgewater, New Jersey. November.

Parsons. 2005. Field Sampling Plan, Operable Unit 1, Quanta Resources Site, Edgewater, New Jersey. May.

# **Geo-Cleanse® Scope of Work and Qualifications**



# Scope of Work

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The following scope of work describes the tasks to be performed by Geo-Cleanse International, Inc. (GCI) to support bench scale testing of saturated soils and groundwater from the Quanta Resources Site.

The goals of the bench scale testing program are to evaluate the effectiveness of the Fenton's reagent and sodium persulfate oxidation on the volatile organic compounds (VOCs) and semivolatile organic compounds (SVOCs) present in saturated soils and groundwater at the site, to estimate total oxidant demand, and to help determine if a Geo-Cleanse® field treatment is warranted at the site. The bench test will be conducted on three types of soils from the site: a silty sand with visible coal tar (SS-1), a silty sand with lower coal tar residuals (SS-2), and a peat sample (P-1). The effectiveness of both of the oxidants, Fenton's reagent and sodium persulfate, will be tested for each of the three soil types. Two types of bench tests will be conducted, a 50% soil/ groundwater slurry test and an autoclave test. In addition, a residual non-aqueous phase liquid (NAPL) test will be conducted on SS-1. The overall bench test is split into three distinct tasks, which are summarized below.

## General Details

Experiments will be conducted by GCI. Soil samples will be analyzed for VOCs, including benzene, toluene, ethylbenzene, and xylene, using EPA Method 8260, SVOCs, including naphthalene and methylnaphthalene and total iron. Treated groundwater from the 20 to 1 oxidant to contaminant ratio test for both oxidants types will be compared to a baseline groundwater sample. Groundwater from these tests for each of the different soil samples will be analyzed for VOCs, SVOCs, As (III), As (V), manganese, phosphates, sulfates, ferrous iron, total iron, total chromium, Cr (VI), total organic carbon (TOC), and total petroleum hydrocarbon (TPH).

GCI requires the following quantities of soil and groundwater: 35 kg of soil and 18 L of groundwater from SS-1, 15 kg of soil and 18 L of groundwater from SS-2, and 15 kg of soil and 18 L of groundwater from P-1 to complete the bench test.

## Task 1: Sample Homogenization and Baseline Sampling

Soil from the site will be homogenized by GCI. Homogenization will be conducted by manually mixing composited samples, exercising all precautions possible to minimize VOC volatilization. Soil mixing will be conducted in large Ziploc-type sealable plastic bags. Homogenized baseline samples will then be collected by GCI. Baseline soil samples will be collected for VOC, SVOC and total iron analysis. The samples will be shipped under standard protocols to the analytical laboratory contracted by GCI. GCI requests that the baseline samples for VOC and SVOC be analyzed with 24-hr turnaround to facilitate the

timeframe of the bench scale test. The baseline contaminant concentrations are required prior to continuing with Task 2.

Baseline groundwater samples will be analyzed for VOCs, SVOCs, As (III), As (V), manganese, nitrates, phosphates, sulfates, ferrous iron, total iron, total chromium, Cr (VI), TOC and TPH. The samples will be shipped under standard protocols to the analytical laboratory contracted by GCI.

## Task 2: Bench Testing

The following is the bench test protocol that will be employed.

- (1) The total contaminant mass will be estimated for each site based upon the baseline sampling results.
- (2) There will be 3 different tests for each soil type and oxidant type (each with a different volume of oxidant and mass ratio):
  - SS-1
    - 10:1 Sample (mass ratio of 10 grams  $\text{H}_2\text{O}_2$  per 1 gram contaminant)
    - 20:1 Sample (mass ratio of 20 grams  $\text{H}_2\text{O}_2$  per 1 gram contaminant)
    - 40:1 Sample (mass ratio of 40 grams  $\text{H}_2\text{O}_2$  per 1 gram contaminant)
  - SS-2
    - 10:1 Sample (mass ratio of 10 grams  $\text{H}_2\text{O}_2$  per 1 gram contaminant)
    - 20:1 Sample (mass ratio of 20 grams  $\text{H}_2\text{O}_2$  per 1 gram contaminant)
    - 40:1 Sample (mass ratio of 40 grams  $\text{H}_2\text{O}_2$  per 1 gram contaminant)
  - P-1
    - 10:1 Sample (mass ratio of 10 grams  $\text{H}_2\text{O}_2$  per 1 gram contaminant)
    - 20:1 Sample (mass ratio of 20 grams  $\text{H}_2\text{O}_2$  per 1 gram contaminant)
    - 40:1 Sample (mass ratio of 40 grams  $\text{H}_2\text{O}_2$  per 1 gram contaminant)
  - SS-1
    - 10:1 Sample (mass ratio of 10 grams  $\text{Na}_2\text{O}_8\text{S}_2$  per 1 gram contaminant)
    - 20:1 Sample (mass ratio of 20 grams  $\text{Na}_2\text{O}_8\text{S}_2$  per 1 gram contaminant)
    - 40:1 Sample (mass ratio of 40 grams  $\text{Na}_2\text{O}_8\text{S}_2$  per 1 gram contaminant)
  - SS-2
    - 10:1 Sample (mass ratio of 10 grams  $\text{Na}_2\text{O}_8\text{S}_2$  per 1 gram contaminant)
    - 20:1 Sample (mass ratio of 20 grams  $\text{Na}_2\text{O}_8\text{S}_2$  per 1 gram contaminant)
    - 40:1 Sample (mass ratio of 40 grams  $\text{Na}_2\text{O}_8\text{S}_2$  per 1 gram contaminant)
  - P-1
    - 10:1 Sample (mass ratio of 10 grams  $\text{Na}_2\text{O}_8\text{S}_2$  per 1 gram contaminant)
    - 20:1 Sample (mass ratio of 20 grams  $\text{Na}_2\text{O}_8\text{S}_2$  per 1 gram contaminant)

- 40:1 Sample (mass ratio of 40 grams  $\text{Na}_2\text{O}_8\text{S}_2$  per 1 gram contaminant)
- (3) For the 10:1 and 40:1 oxidant to contaminant ratio tests for all three soil types and both oxidants, a 50% soil slurry will be prepared by transferring approximately 750 g of soil and 750 ml of groundwater to a 1,000 mL, opaque, high-density polyethylene bottle. Sample volumes and masses may be adjusted slightly to ensure minimal headspace in the reactor (less than ~25 mL).
- (4) For the 20:1 oxidant to contaminant ratio test for all three soil types and both oxidants, a 50% soil slurry will be prepared by transferring approximately 2.5 kg of soil and 2.5 L of groundwater to a 4,000 ml opaque, high-density polyethylene bottle. Sample volumes and masses may be adjusted slightly to ensure minimal headspace in the reactor (less than ~25 ml).
- (5) A soil buffering test will be performed in the GCI laboratory to evaluate the buffering capacity of the soil sample in the following manner:
  - a. A mixture of soil and groundwater will be created.
  - b. A pH meter will be calibrated and set up to record the pH of the mixture continuously.
  - c. An acidic solution will be added drop wise at 5-minute time intervals, until the mixture achieves a steady pH of between 4.0 and 5.0. Time, pH, and amount of acid added to the mixture are recorded to determine the buffering capacity.
- (6) The reactivity of the soil to hydrogen peroxide will also be determined in the GCI lab as follows:
  - a. A set amount of hydrogen peroxide will be added to a sample of soil.
  - b. The reactivity will be determined by observing how the soil reacts to the hydrogen peroxide.
- (7) Solution pH and iron concentration will be adjusted by addition of catalyst.
- (8) Slurries will be allowed to equilibrate for 8 to 16 hours prior to oxidant addition.
- (9) Oxidant will be added. Samples will be gently shaken and allowed to react until residual peroxide or persulfate is consumed in all of the test reactors. Samples will be periodically agitated throughout the test.
- (10) Treated samples will be collected as follows:
  - a. The 20:1 test reactors will be opened and water samples collected for As (III), As (V), manganese, nitrates, phosphates, sulfates, ferrous iron, total iron, total chromium, Cr (VI), TOC and TPH analysis.
  - b. Residual water will be drained from all the other reactors and set aside.
  - c. The treated soils will be dumped into a 1,000 mL beaker (homogenization is not necessary because the samples are agitated during reaction).
  - d. Soil samples will be collected for Total Iron analysis.

- e. Residual water samples will be analyzed for pH and iron concentration by GCI.
- f. Soil and groundwater samples will be shipped by GCI under standard protocols to the appropriate analytical laboratories.

### **Residual NAPL Saturation Test**

- (1) A residual NAPL saturation test will be performed on an SS-1 sample. Approximately 3.0 kg of NAPL saturated soil will be added into a clear, PVC column and attached to a buret stand. This PVC column is fitted with an inlet/outlet port on the top and bottom of the column. The inlet on the bottom of the column will be used to inject oxidant and catalyst. The outlet on the top of the column will be used to discharge leachate from the system.
- (2) Columns will be set-up for both Fenton's reagent and sodium persulfate tests.
- (3) Using the baseline analytical, GCI will calculate the amount of mass present within the columns.
- (4) GCI will then deliver an approximate 20:1 oxidant to contaminant ratio in order to oxidize this mass.
- (5) During the test, GCI will monitor for PID headspace, carbon dioxide and oxygen off-gas to confirm the destruction of NAPL.
- (6) Following the completion of the test, GCI will sample the treated soils for VOCs and SVOCs to determine the destruction of NAPL. GCI will also visually document the changes in the leachate throughout the test and the condition of the soil post-treatment to document NAPL desorption and oxidation.
- (7) If residual NAPL remains following the column test, GCI will sample this material and analyze it for VOCs, SVOCs, and TPH.

### **Autoclave Test**

Analyses will be conducted in an autoclave, a sealed vessel that allows temperature and pressure to be controlled and maintained in ranges similar to those experienced during a field application (typically 80-100°F and 20-25 psi, respectively, but can be modified based upon anticipated conditions). An autoclave also provides the advantage that all inputs and outputs (including volatilized fractions) are controlled and measured, so that a mass balance can be computed. The autoclave experiments will be conducted as follows:

- (1) GCI will utilize the baseline soil analysis of SS-1 to calculate the amount of mass present in the soil samples for each of the oxidant tests. GCI will then calculate a volume of reagent equal to a 20:1 oxidant to contaminant ratio to inject into the autoclave to oxidize the mass present.
- (2) During the test, volumes of solution injected and leachate collected will be monitored. Temperature and pressure will be maintained within ranges anticipated for the field injection. Gases produced by the chemical oxidation reaction will be passed through a silica gel trap (to trap water vapor) and then through a carbon trap (to trap VOCs that pass the silica gel), in order to quantify the volatilized contaminant mass.



(3) The experiment will be concluded when the calculated ratio volume of oxidant has been injected and based upon carbon dioxide and oxygen production, temperature, and pressure, it is believed that approximately 75 to 95% of the organic contaminant mass has been removed from the soil. This is intended to provide constraints on oxidation efficiency.

(4) At the conclusion of the experiment, homogenized post-treatment samples of treated soil, silica gel and activated carbon will be collected and analyzed for target compounds. These data will allow computation of a complete mass balance, and specifically allow the volatilized fraction to be calculated. The results of this mass balance are anticipated to show (1) if the Geo-Cleanse® Process resulted in oxidation of the organic compounds present; (2) fractions and masses of organic compounds not oxidized (i.e., trapped in silica gel or carbon, or transferred to the leachate); (3) a constraint of oxidation efficiency.

# Qualifications

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*Note: Qualifications information obtained from company website: <http://www.geocleanse.com/>*

Since 1995, Geo-Cleanse International, Inc. (GCI) has established a reputation as the premier chemical oxidation company. GCI has the most experience of any chemical oxidation firm and was the first to commercially apply oxidants for a successful NAPL remediation. Our experience, together with independently published results of our work, and a highly qualified staff of professionals, keeps GCI at the top of the industry.

As the chemical oxidation field continues to evolve, GCI has expanded our services to incorporate the advances occurring within the industry, as well as our own proprietary technologies. GCI offers a variety of different chemical oxidation services to our clientele, including bench testing, pilot-scale applications, and full-scale applications. The Geo-Cleanse® Process can effectively treat a wide variety of contaminants in a range of lithologies. To date, GCI has field experience on over 100 sites in many US states, Canada, and Europe. GCI has experience remediating a wide variety of contaminants including petroleum, pesticides, coal tars, and chlorinated hydrocarbons.

## Bench Scale Treatability Studies

GCI maintains a fully equipped and staffed laboratory that enables us to offer our clientele bench scale treatability studies. Bench scale studies provide information about contaminant mass reductions and chemical oxidant efficiencies that can be incorporated into the design of pilot or full-scale treatment programs. During the course of all bench scale treatability studies conducted at GCI, a site-specific catalyst blend is formulated from information and data obtained from native soils and groundwater. The Site specific catalyst formulation is necessary to ensure that subsurface conditions favoring efficient and effective chemical oxidation can be established and maintained. Bench scale treatability studies can help to refine costing for pilot and full-scale chemical oxidation programs.

## GCI Personnel

Geo-Cleanse International, Inc. consists of a professional staff of engineers, geologists, and scientists who play crucial roles in designing and implementing our bench-scale, pilot, and full-scale treatment programs. Our personnel have a wide range of experience in chemical oxidation, environmental science, chemical engineering, chemistry, and geology that help make GCI the premier chemical oxidation company in the industry. Our staff is comprised of Project Managers, Operations Managers, Site Supervisors, Process Specialists, Data Managers, and Sampling Technicians.

## Key Resumes for Quanta Project

- James T. Wilson, President
- MariKay Fish, Director of Operations
- James Daniel Bryant, Project Manager

**Education** Bachelor of Science, Chemical Engineering, New Jersey Institute of Technology

**Certifications** NJDEP Certified UST Closure  
NJDEP Certified Subsurface Evaluation  
40-hr Hazardous Waste Operator Certification  
8-hr Supervisor of Hazardous Waste Operations Certification  
Certified Hazardous Materials Manager

**Qualifications**

- Providing initial estimates, final proposals, and initial Geo-Cleanse reagent requirements
- Conducting sales meeting and presentations to the clients describing the Geo-Cleanse® Process
- Continuously keeping up to date with all Field Supervisors to determine the effectiveness and optimization of the Geo-Cleanse® Process during the injection programs
- Designing the site-specific treatment program for each site based on the contamination involved and geology present
- Interpreting groundwater and soil data to draw conclusions for writing evaluation reports for each site
- Acting as the liaison between clients and GCI to ensure customer satisfaction and overall job success

**Professional Experience**

- **Program Director, Tallahassee, FL**  
Coal Tar contamination
- **Program Director, Savannah, GA**  
Coal tar contamination
- **Program Director, Augusta, GA**  
Coal tar contamination
- **Program Director, Charleston, SC**  
Coal tar contamination
- **Program Director, Somersworth, NH**  
Coal tar contamination
- **Program Director, Orange, CT**  
PCE and TCE contamination
- **Program Director, Valdosta, GA**  
Coal tar contamination
- **Program Director, Saginaw, MI**  
BTEX and CVOC contamination
- **Program Director, Americus GA**  
Coal tar contamination
- **Program Director, Garner, NC**  
TCA and 1,4-Dioxane contamination
- **Program Director, Charlotte, MI**  
Coal tar contamination
- **Program Director, Peterborough, NH**  
TCA contamination
- **Program Director, South Weymouth, MA**  
BTEX contamination
- **Program Director, Allston, MA**  
BTEX contamination
- **Program Director, New Windsor, NY**  
TCA and TCE contamination

- **Program Director, Union, NJ**  
TCE contamination
- **Program Director, Tacoma, WA**  
TCE contamination
- **Program Director, Charleston, SC**  
Chlorobenzene and pesticide contamination
- **Program Director, Bedford, MA**  
TCE and GRO contamination
- **Program Director, Seal Beach, CA**  
TCE contamination
- **Program Director, Moonachie, NJ**  
PCE and TCE contamination
- **Program Director, New Hartford, CT**  
BTEX contamination
- **Program Director, Fort Leonard Wood, MO**  
PCE and TCE contamination
- **Program Director, Clifton, NJ**  
TCE and PCE contamination
- **Program Director, Ogallala, NE**  
PCE contamination
- **Program Director, Burlington, WI**  
PAH contamination
- **Program Director, Kings Bay, GA**  
TCE contamination
- **Program Director, Pueblo, CO**  
RDX and TNT contamination
- **Program Director, Orlando, FL**  
TCE contamination
- **Program Director, Edwards, CA**  
TCE and DCE contamination
- **Program Director, South Weymouth, MA**  
TCE contamination
- **Program Director, Sugarland, TX**  
PCE contamination
- **Program Director, Anniston, AL**  
TCE contamination
- **Program Director, Watertown, CT**  
TCE and PCE contamination
- **Program Director, Jacksonville, FL**  
TCE contamination
- **Program Director, Pensacola, FL**  
TCE and PCE contamination
- **Program Director, Hinesville, GA**  
J4 Jet fuel contamination
- **Program Director, Princeton, IL**  
TCE and PCE contamination
- **Program Director, Grand Rapids, MI**  
TCE and PCE contamination
- **Program Director, Spring Grove, MN**  
TCE and PCE contamination
- **Program Director, Reno, NV**  
BTEX contamination
- **Program Director, Newark, NJ**  
Di-N-Butyl Phthalate
- **Program Director, Piscataway, NJ**  
DRO contamination

- **Program Director, Westfield, NJ**  
PCE contamination
- **Program Director, Woodbridge, NJ**  
BTEX contamination
- **Program Director, Livingston, NJ**  
BTEX contamination
- **Program Director, Pensauken, NJ**  
TCE contamination
- **Program Director, Cincinnati, OH**  
Trichlorobenzene contamination
- **Program Director, Dayton, OH**  
TCE and VC contamination
- **Program Director, Chambersburg, PA**  
TCA, DCA, and DCE contamination
- **Program Director, Aiken, SC**  
TCE and PCE contamination
- **Program Director, Sumpter, SC**  
TCA, TCE, and DCA contamination
- **Program Director, Milan, TN**  
RDX and TNT contamination
- **Program Director, Mercer Island, WA**  
PCE contamination
- **Program Director, Richfield, WI**  
DRO and GRO contamination
- **Program Director, Johnson Creek, WI**  
BTEX contamination
- **Program Director, Milwaukee, WI**  
BTEX contamination
- **Program Director, Montello, WI**  
BTEX contamination
- **Program Director, Glendale, WI**  
PCE contamination
- **Program Director, Madison, WI**  
BTEX contamination
- **Program Director, Winneconne, WI**  
BTEX contamination
- **Program Director, Pewaukee, WI**  
BTEX contamination
- **Program Director, Grandhaven, WI**  
PCE contamination
- **Program Director, Long Island, NY**  
BTEX contamination
- **Program Director, Hales Corner, WI**  
BTEX contamination
- **Program Director, Branford, CT**  
PCE and TCE contamination
- **Program Director, Kansas City, KS**  
Dodecylbenzene contamination

#### Relevant Publications

Maughon, M.J., Casey, C.C., Bryant, J.D., and Wilson, J.T. 2000. Chemical oxidation source reduction and natural attenuation for remediation of chlorinated hydrocarbons in groundwater, in Wickramanayake, G.B., and Gavaskar, A.R. (editors), *Physical and Thermal Technologies: Remediation of Chlorinated and Recalcitrant*

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- Compounds, p. 307-314. *The Second International Conference on Remediation of Chlorinated and Recalcitrant Compounds, May 22-25, 2000, Monterey, California.*
- Bryant, J.D., and Wilson, J.T. 2000. Case studies of in situ chemical oxidation using the Geo-Cleanse® Process. Pages 33-36 in *Proceedings, Abiotic In Situ Technologies for Groundwater Remediation Conference, August 31 - September 2, 1999, Dallas, Texas.* U.S. Environmental Protection Agency EPA/625/R-99/012.
- Bryant, J.D., and Wilson, J.T. 1998. Field demonstration of in-situ Fenton's reagent destruction of DNAPLs. *Environmental Technology*, v. 8, p. 55-59.
- Bryant, J.D., and Wilson, J.T. 1998. Rapid delivery system completes oxidation picture: Remediation of chlorinated solvents at two government sites tests capabilities. *Soil & Groundwater Cleanup*, August/September 1998, p. 6-11.
- Bryant, J.D., and Wilson, J.T. 1999. Fenton's in-situ reagent chemical oxidation of hydrocarbon contamination in soil and groundwater. *Remediation*, Autumn 1999, p. 13-25.

#### Patents

- Wilson, J.T. Remediation Apparatus and Method for Organic Contamination in Soil and Groundwater. U.S. Patent Number 5,525,008. Filed January 11, 1995.
- Wilson, J.T. Remediation Apparatus and Method for Organic Contamination in Soil and Groundwater. U.S. Patent Number 5,611,642. Filed November 13, 1995.

#### Relevant Abstracts and Presentations

- Bryant, J.D., and Wilson, J.T. 1999. Case Studies of in-situ chemical oxidation using the Geo-Cleanse® Process. *Abiotic In-Situ Technologies for Groundwater Remediation, August 31 - September 2, 1999, Dallas, Texas.*
- Maughon, M.J., Casey, C.C., Bryant, J.D., and Wilson, J.T. 2000. Chemical oxidation source reduction and natural attenuation for remediation of chlorinated hydrocarbons in groundwater. *The Second International Conference on Remediation of Chlorinated and Recalcitrant Compounds, May 22-25, 2000, Monterey, California.*

**Education** Bachelor of Arts, Chemistry and Geology, University of Rochester

**Certifications** OSHA 40-hour Hazardous Waste Operations and Emergency Response  
OSHA 8-hour hazardous waste supervisory training  
CPR and First Aid Certified

**Qualifications**

- Acts as the liaison between clients and GCI, working to ensure customer satisfaction and overall job success
- Coordinates all field activities with the injection supervisors
- Works with the technical team to design sites and execute deliverables
- Provides estimates, proposals and presentations to our clients
- Acts as the point of contact for all of our projects when the project managers are in the field

**Professional Experience**

MariKay is responsible for a variety of duties for each site that GCI works on. For each site, MariKay is responsible for:

- Providing initial estimates and initial Geo-Cleanse reagent requirements
- Conducting sales meeting and presentations to the clients describing the Geo-Cleanse® Process
- Serving as the point of contact for all projects when GCI personnel are in the field
- Designing the Geo-Cleanse® Process for each particular site and contaminant
- Coordinating all field activities, including injector installation and injection scheduling
- Scheduling for all GCI employees
- Interpreting groundwater and soil data to draw conclusions for writing evaluation reports for each site
- Acting as the liaison between clients and GCI to ensure customer satisfaction and overall job success

MariKay has worked on the following projects:

- **Director of Operations, Tallahassee, FL**  
Manufactured gas plant; coal tar contamination
- **Director of Operations, Savannah, GA**  
Manufactured gas plant; coal tar contamination
- **Director of Operations, Augusta, GA**  
Manufactured gas plant; coal tar contamination
- **Director of Operations, Garner, NC**  
TCA and 1,4-Dioxane contamination
- **Director of Operations, Charleston, SC**  
Manufactured gas plant; coal tar contamination
- **Director of Operations, Somersworth, NH**  
Manufactured gas plant; coal tar contamination
- **Director of Operations, Saginaw, MI**  
Manufactured gas plant; coal tar contamination
- **Director of Operations, Charlotte, MI**  
Manufactured gas plant; coal tar contamination
- **Director of Operations, Valdosta, GA**  
BTEX and TCA contamination
- **Director of Operations, Wilmington, NC**  
Pentachlorophenol contamination
- **Director of Operations, Americus, GA**  
Manufactured gas plant; coal tar contamination

- **Director of Operations, Peterborough, NH**  
TCA contamination
- **Director of Operations, South Weymouth, MA**  
BTEX contamination
- **Director of Operations, Wallingford, CT**  
Toluene contamination
- **Director of Operations, Allston, MA**  
BTEX Contamination
- **Director of Operations, New Windsor, NY**  
TCA and TCE contamination
- **Director of Operations, Union, NJ**  
TCE contamination
- **Director of Operations, Charleston, SC**  
Pesticide contamination
- **Director of Operations, Tacoma, WA**  
TCE contamination
- **Director of Operations, Moonachie, NJ**  
PCE and TCE contamination
- **Director of Operations, Wallingford, CT**  
TCA contamination
- **Director of Operations, Clifton, NJ**  
TCE contamination
- **Director of Operations, Ogallala, NE**  
PCE contamination
- **Director of Operations, Fort Leonard Wood, MO**  
PCE and TCE contamination
- **Director of Operations, Charleston, SC**  
Chlorobenzene contamination
- **Director of Operations, New Hartford, CT**  
BTEX contamination
- **Director of Operations, Bedford, MA**  
TCE and GRO contamination
- **Director of Operations, South Weymouth, MA**  
TCE contamination
- **Director of Operations, Burlington, WI**  
PAH contamination
- **Director of Operations, Edwards, CA**  
TCE and DCE contamination
- **Director of Operations, Cedar Grove, NJ**  
BTEX contamination
- **Director of Operations, Sugarland, TX**  
Drycleaners Site; PCE contamination
- **Director of Operations, Anniston, AL**  
TCE contamination
- **Director of Operations, Jacksonville, FL**  
PCE and TCE contamination
- **Director of Operations, Orange, CT**  
PCE and TCE contamination
- **Director of Operations, Branford, CT**  
PCE and TCE contamination
- **Director of Operations, Kansas City, KS**  
Dodecylbenzene contamination



**Prior Experience**

**Waste Disposal Industry**

- Provided waste classification, transportation and disposal services
- Coordinated all aspects of these waste disposal projects for large clients, such as the EPA, Georgia EPD, and several large private companies

- Education** Ph. D., Department of Geological Sciences, Columbia University, 1995.  
M. Phil., Department of Geological Sciences, Columbia University, 1993.  
M. Sc., Department of Geology, University of Florida, 1990.  
B. Sc., Department of Geology, University of Florida, 1988.
- Certifications** OSHA 40-hour Hazardous Waste Operations and Emergency Response  
OSHA 8-hour Refresher, Hazardous Waste Operations and Emergency Response  
OSHA 8-hour Hazardous Waste Site Supervisor  
Missouri Registered Geologist #2002022740  
Indiana Licensed Professional Geologist #2122  
Georgia Registered Professional Geologist #PG001826

**Qualifications**

- Responsible for site evaluations, cost proposal preparation, and full project design for international application of innovative in-situ chemical oxidation remediation technologies.
- Development of innovative new technologies, including permanganate injection and in-situ treatment methods for heavy metals.
- Prepare all technical deliverables for clients and regulators, including work plans, health and safety plans, laboratory bench test reports, and post-treatment reports, detailing field and/or laboratory operations, observations, and treatment results.
- Conduct and supervise all aspects of fieldwork, including well installation, soil and groundwater sampling, and field treatment program.
- Manage laboratory for treatment bench testing and for research and development of new remediation technologies. Responsibilities include development and maintenance of chemical hygiene plan, chemical storage and handling, training, and research on novel remediation methods.
- Act as a primary technical representative for the company, including sales presentations, client meetings, and as a participant at industry conferences.
- Obtained DoD research funding to develop in-situ metals and explosives treatment technologies.

Dan has worked on the following projects:

Private Industrial Site / Location Confidential (2002). Conducted bench tests of Fenton's reagent in-situ chemical oxidation on silt and clay soils impacted with very high TCE concentrations (>500 mg/kg). Demonstrated that Fenton's reagent would be an appropriate source-area reduction technology for the site.

Eastland Woolen Mill Superfund Site / Corinna, ME (2002). Designed, proposed, and performed laboratory bench scale testing of Fenton's reagent chemical oxidation treatment of chlorobenzene, dichlorobenzene, and trichlorobenzene-impacted soil and groundwater. Demonstrated that Fenton's reagent was viable for the site, and a request for proposal for field implementation was issued.

Weldon Spring Site Remedial Action Project / St. Charles, MO (2001-2002). Designed, proposed, implemented, and managed laboratory bench scale testing and field pilot test of in-situ permanganate chemical oxidation treatment of chlorinated hydrocarbons in a fractured limestone bedrock aquifer at this Department of Energy facility. Negotiated partnering arrangement with a major environmental consulting firm for onsite construction and site superintendence.

Stratford Army Engine Plant, Innovative Chromium Treatment Technology Demonstration / Stratford, CT (1999-2002). Designed, proposed, and currently managing a demonstration of an innovative technology to address hexavalent chromium in groundwater. Funding was received from the Environmental Security Technology Certification Program, a competitive Department of Defense grant program.

Naval Air Station South Weymouth Jet Fuel Pipeline Site / South Weymouth, MA (2002). Designed, implemented and managed an in-situ Fenton's reagent chemical oxidation treatment of fuel hydrocarbons. The site was a

protected wetlands area with very shallow depth to groundwater and low permeability clay soil. Interacted with local and state conservation committees for wetlands permitting and Massachusetts Contingency Plan authorities.

Private Industrial Site / Savannah, GA (2002). Designed, proposed, and implemented Fenton's reagent bench tests for in-situ treatment of MGP wastes. Successful bench test led to field pilot test, and is anticipated to be a full-scale, multi-million dollar remediation.

Private Industrial Site / Location Confidential (2002). Designed, proposed, and implemented Fenton's reagent bench tests for in-situ treatment of MGP wastes. A full-scale remediation was designed and implemented on the basis of the successful bench test.

Private Industrial Client / Peterborough, NH (2002). Designed and implemented bench scale testing of in-situ Fenton's reagent chemical oxidation treatment of 1,1,1-TCA in groundwater. Field pilot test was implemented on the basis of the bench test results.

Private Industrial Client / Garner, NC (2002). Designed, proposed, and implemented a bench test of in-situ Fenton's reagent chemical oxidation treatment of 1,4-dioxane and 1,1,1-TCA in groundwater. Field pilot test was implemented on the basis of the bench test results.

Former East Kelly Air Force Base / San Antonio, TX (2002). Designed, proposed, and implemented a permanganate bench test, a field iodide tracer test, and side-by-side field pilot tests of enhanced bioremediation with vegetable oil and of permanganate in-situ chemical oxidation. Demonstrated that anaerobic bioremediation with vegetable oil was the most viable option for the site, and full-scale implementation was completed. Site is currently in monitoring phase.

Private Industrial Client / Lebanon, PA (2002). Designed, proposed, and implemented side-by-side Fenton's reagent and permanganate oxidation bench tests to address very low (<2 ug/L) concentrations of pesticides in groundwater. Demonstrated that neither oxidant was effective against the contaminants of concern at the site, and recommended alternative technologies.

Ogallala Water Supply Superfund Site / Ogallala, NE (2002). Designed, proposed, and implemented a field pilot test of permanganate in-situ chemical oxidation using direct-push injection techniques. The EPA anticipates issuing a ROD identifying permanganate ISCO as the selected remedy.

Private Industrial Client / Multiple MGP Sites (2002). Designed, proposed, and implemented Fenton's reagent bench tests for five MGP sites. Successful bench tests led to field pilot tests at three of the five sites, and further to full-scale implementation at two of the sites.

Chemical Leaman Tank Lines Superfund Site / Bridgeport, NJ (2000-2002). Designed, proposed, and implemented a two-phase bench scale test of Fenton's reagent oxidation of TCE DNAPL and residual breakdown products associated with petroleum hydrocarbons at an EPA Superfund site. Assisted with design negotiations for a field pilot test with EPA. Field pilot test is planned for 2005.

Private Industrial Client / Panama City, FL (2001-2002). Designed, proposed, and implemented a bench and field pilot test of permanganate oxidation of low-level (<100 ug/L) TCE and residual breakdown products using a direct-push injection method.

Naval Weapons Industrial Research Plant / Bedford, MA (2000-2002). Designed and managed in-situ Fenton's reagent chemical oxidation treatment of petroleum hydrocarbons from a leaking UST in dense glacial till matrix. Site was technically challenging for very steep hydraulic gradient and treatment under existing buildings.

Naval Training Center / Orlando, FL (2000-2002). Designed, proposed, and managed in-situ Fenton's reagent chemical oxidation treatment of TCE DNAPL site. Tasks included performing additional site delineation with direct-push approaches to complete project design.

NSB Kings Bay / Kings Bay, GA (1999-2002). Designed, proposed, and implemented a four-phase treatment program over 3 years at the site, including Fenton's reagent injection and vegetable oil injection. The Navy received

an environmental awareness award from the Georgia DEP based upon the results, and was allowed to shut off a long-term pump-and-treat system. The Navy has utilized the results from this site as an example of aggressive source reduction followed by enhanced natural attenuation as a groundwater remedy.

Naval Weapons Station / Seal Beach, CA (2001). Designed and managed in-situ Fenton's reagent chemical oxidation pilot test of TCE DNAPL in an alkaline aquifer. The Navy has recommended implementation of full-scale treatment (pending).

Fort Detrick / Frederick, MD (2001). Designed, proposed, and performed Fenton's reagent oxidation tests for PCE in a dolomitic fractured bedrock site. Recommended alternative technologies based upon bench test results indicating Fenton's reagent was not viable for the site.

Pueblo Chemical Depot / Pueblo, CO (2000-2001). Designed, proposed, and implemented laboratory bench scale testing and field pilot tests of in-situ Fenton's reagent chemical oxidation treatment of dissolved explosives in groundwater at this Army facility.

Naval Air Station South Weymouth Building 81 / South Weymouth, MA (2000-2001). Designed, proposed, and implemented Fenton's reagent treatment of PCE and BTEX in a fractured bedrock aquifer and clay till overburden.

Private Industrial Client / Houston, TX (2000). Designed, proposed, and implemented full-scale in-situ Fenton's reagent chemical oxidation treatment of very low level ( $<100$  ug/L) chlorinated hydrocarbons in groundwater, followed with permanganate chemical oxidation to address low-level residual solvent concentrations.

Edwards Air Force Base Site N7 / Edwards, CA (2000). Designed, proposed, and implemented a field pilot test of permanganate oxidation in a fractured bedrock aquifer. Results were featured in an article in *Ground Water Currents* (published by the U.S. Environmental Protection Agency) in April 2002. A ROD is being issued selecting permanganate in-situ chemical oxidation for the remainder of the site, with full-scale implementation planned for 2005.